A. Quality Assurance and Surveillance Plan

Facility Information

Facility name: Heartland Greenway Storage Site (HGSS)

Facility contact: David Giles
2626 Cole Ave., Dallas, Texas, USA 75204
Phone: (210) 880-6000; Email: dgiles@navco2.com

Well location: Taylorville, Christian County, Illinois
39°35'47.1"N, 89°16'12.4"W

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Project Management

A.1. Project/Task Organization

A.1.a/b. Key Individuals and Responsibilities

The project shall be owned and operated by Heartland Greenway Carbon Storage, LLC (HGCS) who will be assisted by several subcontractors. HGCS will serve as the lead on all project tasks while supervising the performance of subcontractors for each individual task. Tasks related to testing and monitoring that will require supervision for purposes of quality control and assurance can be broadly divided into:

1. Groundwater Sampling and Analysis
2. Well Logging
3. Mechanical Integrity Testing
4. Injection Monitoring
5. CO_2 Stream Sampling and Analysis
6. Geophysical Monitoring

HGCS will assign key personnel to the following positions HGSS project implementation:

1. Project Engineer(s)
2. Site Safety Manager(s)
3. Environmental Manager(s)
4. Pipeline Manager(s)

A.1.c. Independence from Project QA Manager and Data Gathering

Most of the physical samples collected, and data gathered as part of the testing and monitoring program will be analyzed, processed, or witnessed by third parties independent and outside of the project management structure. HGCS will furnish a final list of vendors, subcontractors, and independent testing labs that will have access to the monitoring data generated at the HGSS facility.

A.1.d. QA Project Plan Responsibility

HGCS will be responsible for maintaining and distributing official, approved QASP. HGCS will periodically review this QASP and consult with the UIC Program Director if/when changes to the plan are warranted.

A.2. Problem Definition/Background

A.2.a. Reasoning

HGSS's testing and monitoring program has operational monitoring, verification, and environmental monitoring components. Operational monitoring guarantees safety with all procedures associated with injection of CO_2, monitor the response of the storage unit, and the movement of the CO_2 plume. Critical monitoring parameters include: annulus (pressure/volume), storage unit, above seal strata, and USDWs. Other monitoring parameters include injection rate, total mass & volume injected, and injection well temperature profile. The verification component of the HGSS TM plan will provide data to evaluate if leakage of CO_2 through the caprock is occurring. This includes pulse neutron logging, pressure, and temperature monitoring. This monitoring includes pulse neutron logging and ground water monitoring.

A risk-based testing and modeling program has been developed for HGSS based on:

1. The results from computational modeling-driven storage complex delineation, and
2. A quantitative risk assessment that factored in major risks posed by HGSS to the safety of underground drinking water resources, local public, and environment.

The objective of HGSS testing and monitoring program is to demonstrate that project activities are protective of human health and the environment. To help achieve this goal, this Quality Assurance Surveillance Plan (QASP) has been developed to ensure the quality and standards of the testing and monitoring program and to specifically meet the requirements set forth in Section 40 CFR 146 of the UIC regulations.

A.2.b. Reasons for Initiating the Project

The objective of the HGSS project is to develop a safe and commercially viable CO_2 injection and storage project in Christian County, Illinois by leveraging storage capacity of the extensively studied Mt Simon sandstone reservoir. HGCS will demonstrate the viability of injecting commercial volumes of CO_2 while abiding to strict environmental health and safety standards and adopting best practices in project operation, maintenance, and monitoring.

A.2.c. Regulatory Information, Applicable Criteria, Action Limits

Owners or operators of CO_2 injection wells are required to perform several types of activities during the lifetime of the project to ensure that the injection well maintains its mechanical integrity, that fluid migration and the extent of pressure elevation are within the limits described in the permit application, and that there is negligible threat to underground sources of drinking water (USDWs), public health and safety, and the local environment. Specific monitoring procedures include internal and external well mechanical integrity tests (MITs), injection well pressure and rate monitoring during operation, monitoring of ground water quality, and tracking of the CO_2 plume and associated pressure front. This QASP discusses methods of measurement as well as the steps HGCS will take to ensure that the quality of all the gathered data provides confidence in making project decisions.

A.3. Project/Task Description

A.3.a/b. Summary of Work to be Performed

Table A-1 and Table A-2 below describe HGSS testing and monitoring tasks, reasoning, techniques, and frequencies.

Table A-1. Summary of testing and monitoring activities, technique and rational.

Activity	Location(s)	Method	Analytical Technique	Purpose [with CCS Regulation Section reference]
Carbon dioxide stream analysis	Compressor; post-dehydration	Direct sampling	Chemical analysis	Analysis of injectate 40 CFR 146.90(a)

Activity	Location(s)	Method	Analytical Technique	Purpose [with CCS Regulation Section reference]
Groundwater quality	Shallow observation wells, above-zone wells	Shallow groundwater sampling (ASTM-D4448)[1] And Kuster Flow Sampler (deep)	Chemical analysis	Groundwater monitoring 40 CFR 146.90(d)
Injection rate and volume	NCV-[1-6] surface wellheads	Flow meter	Continuous Direct measurement	Continuous monitoring of injection rate and volume 40 CFR 146.90(b)
Injection pressure	NCV-[1-6] surface wellheads	Wellhead pressure/Temperature gauge	Continuous Direct measurement	Continuous monitoring of injection pressure 40 CFR 146.90(b)
Annular pressure	NCV-[1-6] surface wellhead	Annular Pressure Gauge	Continuous Direct measurement	Continuous monitoring of annulus pressure 40 CFR 146.90(b)
Annular Volume	NCV-[1-6], Surface Annular Pressure Vessel	Annular volume gauge	Continuous Direct measurement	Continuous monitoring of annulus pressure 40 CFR 146.90(b)
Downhole pressure/ temperature *(injection zone)*	NCV-[1-6] NCV-OB-MS-[1-6] (Mt. Simon)	Downhole P/T gauges	Direct measurement	Continuous monitoring of injection pressure 40 CFR 146.90(g)(1)
Corrosion monitoring	Post-compression and dehydration	Corrosion Coupons	Chemical analysis	Corrosion monitoring and casing inspection 40 CRF 146.90(c)
Mechanical integrity	NCV-[1-6] NCV-OB-I-[1-6] NCV-OB-MS-[1-6]	Internal – Annular pressure gauge monitoring	Direct Measurement	Demonstration of internal and external mechanical integrity

[1] American Society for Testing and Materials (ASTM) Standard D4448-01. 2019. Standard Guide for Sampling Ground-Water Monitoring Wells, ASTM International, West Conshohocken, PA. DOI: 10.1520/D4448-01R19, www.astm.org.

Activity	Location(s)	Method	Analytical Technique	Purpose [with CCS Regulation Section reference]
		External – Distributed Temperature Sensing (DTS)	Distributed Indirect Measurement	40 CFR 146.89
Pressure fall-off testing	NCV-[1-6]	Pressure gauge	Direct measurement	Pressure fall-off testing 40 CFR 146.90(f)
CO_2 plume monitoring	*NCV-[1-6]:* Mount Simon *NCV-OB-MS-[1-6]:* Mount Simon, Eau Claire, Argenta *NCV-OB-I-[1-6]*: Ironton formation	Downhole P/T gauges	Direct Measurement	Plume and elevated pressure tracking 40 CFR 146.90(g)
	Area of Review (AoR), All injection, in-zone and above-zone wells	Time-lapse 3D Vertical Seismic Profile (VSP), Pulsed Neutron Capture (PNC) logs	Indirect measurement and mapping	

Table A-2. Monitoring Frequencies by Method and Project Phase

Monitoring Category	Monitoring Method		Baseline Frequency	Injection Phase Frequency (30 years)	Post-Injection Frequency (20 years)
Monitoring Plan Update	Reviewed every 5 years. Updated as required		N/A	As required	As required
CO_2 **Injection Stream Analysis**	Continuous monitoring of injection stream composition		N/A	Continuous	N/A
CO_2 **Injection Process Monitoring**	Continuous monitoring of injection process (injection rate, pressure, and temperature; annulus pressure and volume)		N/A	Continuous	N/A
Hydrogeologic Testing	Injection well pressure fall-off testing		Once, prior to injection	1 every 5 years	N/A
Injection Well Mechanical Integrity Testing	*Internal*	Continuous annulus pressure monitoring of pressurized annulus	After well completion *(injectors)*	Continuous *(injectors)*	NA
	External	Distributed Temperature Sensing	After well completion *(injectors/monitors)*	Continuous *(injectors/monitors)*	Continuous *(monitors)*
Corrosion Monitoring	Corrosion coupon testing (Well and pipeline materials)		N/A	Quarterly	N/A
Groundwater Quality and Geochemistry Monitoring (Above-Zone)	Above-Zone & Shallow Groundwater Fluid sampling		Quarterly, 1 year prior to injection	Quarterly*	1 every 5 years*
Direct Pressure Monitoring	Electronic P/T gauges		1 year prior to injection	Continuous	Continuous
Indirect Plume Monitoring Techniques	*Fiber/Wireline*	DTS-DAS	1 year prior to injection	Continuous	Continuous
		PNC Logging	1 year prior to injection	Variable (min. 1 every 5 years)	1 every 5 years

Monitoring Category	Monitoring Method		Baseline Frequency	Injection Phase Frequency (30 years)	Post-Injection Frequency (20 years)
	Seismic	Timelapse 3D DAS-VSP Surveys	1 year prior to injection	1 every 5 years	1 every 5 years

*Frequency to be reduced based on baseline results and project specific benchmarks.

A.3.c. Geographic Locations

Figure A-1 below displays the locations of the HGSS injection wells (NCV-[1-6]) and the array of monitoring wells which will support collection of the various characterization and monitoring measurements needed to track development of the CO_2 plume within the injection zone and identify/quantify any potential release of CO_2 from containment that may occur. To decrease the impact of CCS-related activities on the local ecosystem and increase operational efficiency, the project will contain a total of seventeen well nests (locations containing several wells) (Figure A-1). The current monitoring well locations are approximate and subject to landowner approval. The HGSS monitoring network will consist of six in-zone monitoring wells (NCV-OB-MS[1-6]) drilled to the Precambrian basement with completions in the Mt. Simon and Argenta, six above-zone monitoring wells (NCV-OB-I[1-6]) drilled to just above the storage complex with completions in the Ironton Formation, and seventeen shallow groundwater monitoring wells (NCV-OB-SG[1-17]) drilled to sample shallow USDWs.

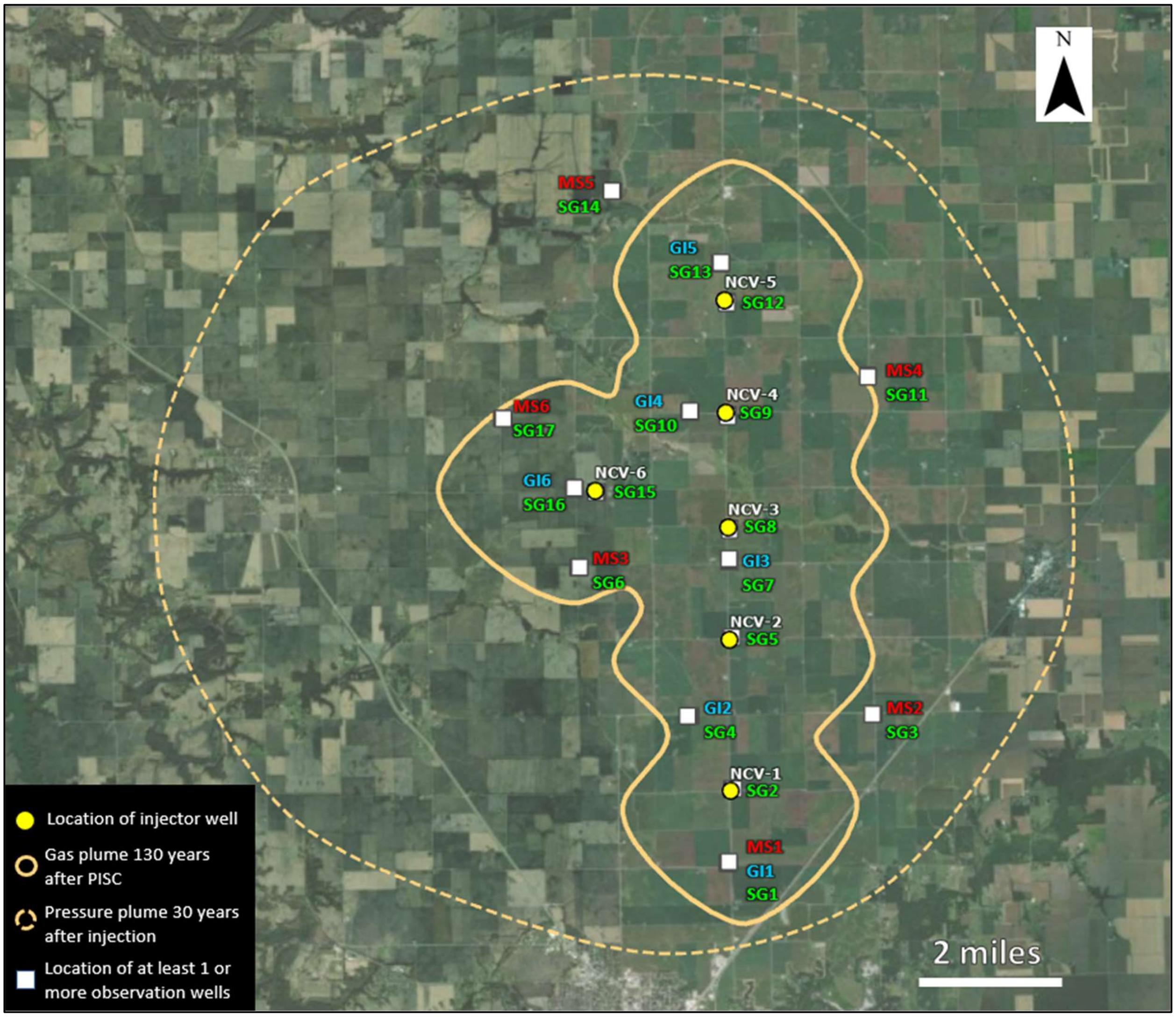

Figure A-1. The HGSS showing the locations of injection wells (yellow circles), in-zone monitoring wells (white squares with red labels), above-zone monitoring wells (white squares with blue labels), shallow groundwater monitoring wells (white squares with green labels), maximum CO_2 plume extent (solid yellow line), maximum pressure plume extent (dashed yellow line), and pipeline within the storage site.

A.3.d. Resource and Time Constraints

No resource or time constraints have been currently identified for this project.

A.4. Quality Objectives and Criteria

A.4.a. Performance/Measurement Criteria

The QA objective for monitoring is to generate and implement procedures for subsurface monitoring, field sampling, laboratory analysis, and reporting which will provide results that will meet the characterization and non-endangerment goals of the HGSS project. Please refer to Table A-3 through

Table A-8 for specifications and action limits of technologies used for HGSS monitoring and testing. Please refer to Attachment A of this QASP for detailed specifications from vendor product sheets. Please refer to Attachment B of this QASP for CO_2 composition and pipeline specifications and Attachment C for wireline-based well logging quality assurance protocols. Please refer to Attachment D for generalized design schematics for the different monitoring well types.

Key testing and monitoring areas for the HGSS project include:

CO_2 Stream Analysis

1. CO_2 Purity (% v/v, [GC])
2. Water content (Lb./MMscf)
3. Nitrogen (N_2, mol% dry basis)
4. Argon (Ar, mol% dry basis)
5. Oxygen (O_2, mol% dry basis)
6. Total Hydrocarbons (THC, mol%)
7. Hydrogen (H, mol%)
8. Glycol (ppm v/v)
9. Hydrogen Sulfide (H_2S ppm v/v)
10. Total Sulfur (S, ppm v/v)
11. Oxygen (O_2, ppm v/v)
12. Carbon Monoxide (CO, ppm v/v)

CO_2 Injection Process Monitoring

1. Process Control System Programable Logic Controllers
   a. Allen Bradley ControlLogix Platform
   b. Allen Bradley ControlLogix Platform
2. Measurement
   a. Meter - Daniel Sr. Orifice Meters
   b. Sensor - Emerson Multivariable Transmitter (DP, Static Pressure and Temperature). 4088B or similar or standalone sensors.
   c. Flow Computer - Emerson FB2200/ROC800 or OMNI Flow Computer 6000/6000E
   d. Gas Chromatograph - Rosemount 700XA or Rosemount 500
3. Instrumentation
   e. Pressure - Emerson Rosemount 2088 or 3051 transmitters
   f. Temperature - Emerson Rosemount 644 or 3144P transmitters
   g. Level - Emerson Rosemount 3051L for differential pressure level or 3300 Guided Wave Radar
   h. Moisture and 02 Analyzer at Capture Sites
4. Injection well annulus pressure and annular volume monitoring system

Hydrogeologic Testing

1. Pressure fall-off testing

Mechanical Integrity Testing (MIT)

1. Temperature (DTS), cement-bond logging
2. Continuous annular pressure monitoring

Corrosion Monitoring

1. Injection well corrosion coupon monitoring

Above-Zone Monitoring: Shallow Groundwater Sampling (Quaternary USDWs)

1. Aqueous geochemistry

Above-Zone Monitoring: Deep Fluid Sampling (Ironton formation)

1. Aqueous geochemistry

Direct Pressure/Temperature Monitoring

1. Pressure/temperature from subsurface in-situ gauges above packers
2. Pressure/temperature from surface gauges

Indirect Plume Monitoring: Subsurface

1. PNC Logging
2. DTS
3. Timelapse 3D DAS-VSP or 3D surface seismic

Table A-3. Technology specifications for the CO_2 Process Monitoring

Parameters	Methods	Detection Limit/Range	Typical Precisions	QC Requirements	Calibration Frequency
Booster pump discharge pressure	ISO/IEC 17025 (2017)[2]	+/- 0.001 psi / 0-3000 psi	+/- 0.01 psi	Annual Calibration of Scale (3rd party)	As suggested by manufacturer
Operational Annular Pressure Monitoring	ISO/IEC 17025 (2017)	+/- 0.001 psi / 0-3000 psi	+/- 0.01 psi	Annual Calibration of Scale (3rd party)	As suggested by control system/gauge manufacturer
Wellhead Injection pressure (*PPS PPS31 Wellhead Pressure Logger or similar product*)	ISO/IEC 17025 (2017)	0-15,000 psi	±0.03% FS	Annual Calibration of Scale (3rd party)	As suggested by gauge manufacturer
Orifice Meters -Injection mass flow rate (Emerson Coriolis mass flow meter)	AGA Report 3 API Chapter 14 part 3[3]	547.95-3561.64 tonnes (metric)/day	±0.1 of rate	Annual Calibration of Scale (3rd party)	As suggested by gauge manufacturer

[2] International Organization for Standardization (ISO) / International Electrotechnical Commission (IEC) 17025, 2017. General requirements for the competence of testing and calibration laboratories, Third Edition.
[3] API MPMS Ch. 14 / AGA Report No. 3: Orifice Metering of Natural Gas and Other Related Hydrocarbon Fluids - Concentric, Square-edged Orifice Meters., 2016.

Table A-4. Specifications for MIT Testing and Monitoring technologies

Logging Tool	Analytical Methods	Detection Limit/Range	Typical Precisions	QC Requirements	Calibration Frequency
Ultrasonic Cement Bong Log (SLB USI Tool)	Vendor best practice	0-10 MRayl	±0.5 MRayl	Vendor Calibration (3rd party)	Per Vendor Discretion
Pulse Neutron Capture Logging (SLB Pulsar and RST Tool)	Vendor best practice	Porosity: 0 to 60 pu	TBD	Vendor Calibration (3rd party)	Per Vendor Discretion
Distributed Temperature Sensing (Silixa XT-DTS system)	Vendor best practice	-40ºF to 149ºF	0.01ºC	Vendor Calibration (3rd party)	Per Vendor Discretion

Table A-5. Specifications for Corrosion Coupon Monitoring

Parameters	Analytical Methods	Detection Limit/Range	Typical Precisions	QC Requirements	Calibration Frequency
Mass	NACE RP0775-2005[4]	0.005 mg	±2%	Annual Calibration of Scale (by unidentified 3rd party)	Annual
Thickness	NACE RP0775-2005	0.001 mm	±0.005 mm	Factory Calibration	Per manufacturer's suggestion

[4] The National Association of Corrosion Engineers (NACE) Standard RP0775, (2005). *Preparation, Installation, Analysis, And Interpretation Of Corrosion Coupons In Oilfield Operations*, Houston, TX. ISBN 1-57590-086-6.

Table A-6. Summary of Analytical and Field Parameters for Shallow and Deep Above-Zone Fluid Sampling

Parameters	Analytical Methods[(1)]	Detection Limit/Range	Typical Precisions	QC Requirements
Cations: Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb, Se, and Tl	ICP-MS EPA Method 6020B[5]	0.001 to 0.1 mg/L (analyte, dilution and matrix dependent)	±15%	Daily Calibration; blanks, duplicates and matrix spikes at 10% or greater frequency
Cations: Ca, Fe, K, Mg, Na, and Si	ICP-OES EPA Method 6010D[6]	0.005 to 0.5 mg/L (Analyte, dilution and matrix dependent)	±15%	Daily Calibration; blanks, duplicates and matrix spikes at 10% or greater frequency
Anions: Br, Cl, NO_3, and SO_4	Ion Chromatography EPA Method 300.0[7]	0.02 to 0.13 mg/L (analyte, dilution and matrix dependent)	±15%	Daily Calibration: blanks and duplicates at 10% or greater frequency
Dissolved CO_2	Coulometric Titration ASTM 513-16[8]	25 mg/L	±15%	Duplicate measurement; standards at 10% or greater frequency
Total Dissolved Solids	Gravimetry APHA 2540C[9]	12 mg/L	±15%	Balance calibration, duplicate analysis
Alkalinity	APHA 2320B[10]	4 mg/L	±3 mg/L	Duplicate Analysis
pH (field)	EPA 150.1[11]	2 to 12 pH units	±0.2 pH unit	User Calibration per manufacturer recommendation

[5] U.S. EPA. 2014. "Method 6020B (SW-846): Inductively Coupled Plasma-Mass Spectrometry," Revision 2. Washington, DC.
[6] U.S. EPA. 2014. "Method 6010D (SW-846): Inductively Coupled Plasma-Optical Emission Spectrometry," Revision 4. Washington, DC.
[7] U.S. EPA. 1993. "Method 300.0: Methods for the Determination of Inorganic Substances in Environmental Samples" Revision 2.1. Washington, DC
[8] ASTM Standard D513-16. 1988 (2016). "Standard Test Methods for Total and Dissolved Carbon Dioxide in Water," ASTM International, West Conshohocken, PA. DOI: 10.1520/D0513-16, www.astm.org.
[9] American Public Health Association (APHA), SM 2540 C, Standard Methods for the Examination of Water and Wastewater, APHA-AWWA-WPCF, 20th Edition (SDWA) and 21st Edition (CWA).
[10] Method 2320 B, Standard Methods for the Examination of Water and Wastewater, APHA-AWWA-WPCF, 21st Edition, 1997.
[11] U.S. EPA. 1971 (1982). "Method 150.1: pH in Water by Electromagnetic Method", Cincinnati, OH.

Specific Conductance (field)	APHA 2510[12]	0 to 200 mS/cm	±1% of reading	User calibration per manufacturer recommendation
Temperature (field)	Thermocouple	-5 to 50ºC	±0.2ºC	Factory Calibration
Isotopes: $\delta^{13}C$ of DIC	Isotope Ratio Mass spectrometry	12.2mg/L HCO_3^- for $\delta^{13}C$	±0.15‰ for $\delta^{13}C$	10% duplicates; 4 standards/batch

[(1)] **Abbreviations:** ICP=inductively coupled plasma; MS= mass spectrometry; OES= Optical emission spectrometry; GC-P=Gas chromatography-Pyrolysis

Table A-7. Summary of Direct Plume Monitoring Parameters for Downhole Gauges.

Parameters	Methods	Detection Limit/Range	Typical Precisions	QC Requirements	Calibration Frequency
Downhole Temperature ***(Baker Hughes SureSENS QPT ELITE pressure/temperature gauge)***	Unknown	77ºF to 302ºF (25ºC to 150ºC)	0.27ºF (0.15ºC)	Initial Manufacturer Calibration	Not required on downhole gauges
Downhole Pressure ***(Baker Hughes SureSENS QPT ELITE pressure/temperature gauge)***	Unknown	200 psi to 10,000 psi (13.8 bar to 689.5 bar)	±0.015%, 1.5 psi at full scale	Initial Manufacturer Calibration	Not required on downhole gauges

[12] American Public Health Association (APHA), SM 2510, 1992. Standard Methods For the Examination of Water and Wastewater., APHA-AWWA-WPCF, 23th Edition.

Table A-8. Actionable Testing and Monitoring Outputs.

Activity or Parameter	Project Action Limit	Detection Limit	Anticipated Reading
DTS *(Silixa Distributed temperature sensing system)*	Action to be taken when a temperature anomaly is observed	Refer to Table A-4 for detection limits	Difference between Profiles observed during baseline & injection stream temperature
PNC Logging *(SLB Pulsar/RST tool)*	Action to be taken when a CO_2 saturation anomaly is observed	Refer to Table A-4 for detection limits	Brine saturated ~ 60 CO_2 saturated ~ 8
Annular Pressure Monitoring	<3% pressure loss over 1 hour	Refer to Table A-3	>3% pressure loss over 1 hour
Surface/downhole pressure *(Baker Hughes Downhole P/T gauges)*	Reservoir pressure >80% fracture gradient	refer to Table A-7	Profiles TBD during baseline
Above-zone Water quality (fluid sampling)	Action to be taken when chemical profile anomaly is observed	refer to Table A-6 for analyte detection limits	Profiles TBD during baseline
Above-confining-zone pressure *(Baker Hughes downhole pressure/temperature gauge)*	Action will be taken when a pressure/temperature anomaly occurs	refer to Table A-7	Profiles TBD during baseline
Plume monitoring/tracking (*DAS-3D VSP, 3D Seismic*)	Action to be taken if plume is observed outside modelled spatial limits/geologic zones	Dependent on feasibility study and geologic conditions	Profiles TBD during baseline

A.4.b. Precision

For groundwater sampling, data accuracy is evaluated by the collection and analysis of field blanks to test sampling procedures and matrix spikes to test lab procedures. Field blanks will be acquired no less than one per sampling event to spot check for sample bottle contamination. Assessment of analytical precision will be the responsibility of the individual laboratories.

Table A-3 through Table A-8 summarize the specifications and precision information of each monitoring method. For direct pressure and logging measurements, precision information is presented in Table A-9 through Table A-12 below. Table A-8 shows the acceptable monitoring parameters.

A.4.c. Bias

Assessment of analytical bias is to be the responsibility of the individual laboratories, as documented in their standard operating procedures and analytical methodologies. For direct pressure or logging measurements, there is no bias.

A.4.d. Representativeness

Data representativeness is the degree to which data accurately and precisely represents a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. The HGSS sampling network is designed to provide data representative of site-specific conditions. For analytical results of individual groundwater samples, representativeness is estimated by ion and mass balances. Ion balances with ±10% error or less is considered valid. Mass balance assessment is used in cases where the ion balance is greater than ±10% to help identify the source of error. For a sample and its duplicate, if the relative percent difference is greater than 10%, the sample may be considered non-representative.

A.4.e. Completeness

Data completeness is a measure of the quantity of valid data obtained from a measurement system compared to the amount that was expected to be obtained under normal conditions. It is anticipated that data completeness of 90% for groundwater sampling will be acceptable to meet monitoring goals. For direct pressure and temperature measurements, it is expected that data will be recorded no less than 90% of the time.

A.4.f. Comparability

Data comparability is the confidence with which one data set may be compared to another. The data sets generated by the HGSS project will be comparable to future data sets, due to the use of standard methods and the application of QA/QC procedures. If historical groundwater quality data becomes available from other sources, their applicability to the project and level of quality will be assessed prior to utilization with data collected by HGCS . Direct pressure, temperature, and logging measurements will be directly comparable to previously obtained data.

A.4.g. Method Sensitivity

Table A-9 through Table A-12 provide additional details on direct gauge and logging tool specifications and sensitivities. Please refer to Table A-3 through Table A-8 above regarding indirect non-gauge-based method sensitivities.

Table A-9. Pressure and Temperature—Downhole Gauge Specifications.

Device: *Baker Hughes SureSENS QPT-Elite Electronic Downhole Pressure-Temperature Gauge*	
Parameter	**Value**
Calibrated working pressure range	200 psi to 10,000 psi
Initial pressure accuracy	+-0.015% (1.5 psi at full scale)
Pressure resolution	0.0001 psi
Pressure drift stability	2.0 psi per year at full scale
Calibrated working temperature range	77°F to 302°F (25°C to 150°C)
Initial temperature accuracy	0.27°F (0.15°C)
Temperature resolution	0.0001°F
Temperature drift stability	0.018°F (<0.01°C)
Max temperature	302°F

Table A-10. Representative Logging Tool Specifications.

Parameter	USI	RST	DAS	DTS	Pulsar
Logging speed	1800 ft/hr.	150 ft/hr.	NA	NA	1000 ft/hr.
Vertical resolution	6 inches	24 inches	*25cm	*25-50 cm	15 inches
Investigation	Casing-to-cement interface	4-6 inches	*0-24.8 miles	At fiber location	10-16 inches
Temperature rating	350°F (175°C)	300°F (150°C)	500°F	149ºF	350°F (175°C)
Pressure rating	20,000 psi	15,000 psi	20,000 psi	20 psi	15,000 psi

** Typical vertical resolution for a VSP survey. Resolution will depend on final VSP survey design.*

Table A-11. Pressure Field Gauge-Wellhead Pressure-Temperature Gauge.

Device: ***Pioneer PPS31 Wellhead Pressure Logger***	
Parameter	**Value**
Calibrated working pressure range	0-15,000 psi
Initial pressure accuracy	±0.03% FS
Pressure resolution	0.0003% FS
Pressure drift stability	<3
Calibrated working temperature range	-4ºF to 158ºF
Initial temperature accuracy	±0.09 ºF (0.5ºC)
Temperature resolution	0.02 ºF (0.01 ºC)
Max temperature	158 ºF

Table A-12. Mass Flow Rate Field Gauge—CO_2 Mass Flow Rate.

Parameter	**Value**
Calibrated working flow rate range	2739.73-3561.64 tonnes (Metric)/day
Initial mass flow rate accuracy	0.1000 (% rate)
Mass flow rate resolution	0.00
Mass flow rate drift stability	To be determined

A.5. Special Training/Certifications

A.5.a. Specialized Training and Certifications

Measurement, instrument and electrical, and pipeline technicians operating pipeline monitoring and measurement equipment will be trained as follows:

1) Measurement Technicians
   a) CO_2 handling and calibration
   b) Operator Qualifications for operations of Hazardous Materials Pipeline
   c) First aid, CPR, Driving, fatigue management

d) OSHA 10 HR training
e) Hazwoper- Emergency response training
f) Electrical safety for non-qualified personnel

2) Instrument & Electrical Technician
   a) NFPA 70-E Training
   b) Electrical safety for qualified personnel
   c) CO_2 handling and calibration
   d) Operator Qualifications for operations of Hazardous Materials Pipeline
   e) First aid, CPR, Driving, fatigue management
   f) OSHA 10 HR training
   g) Hazwoper- Emergency response training

3) Pipeline Technicians
   a) Line Locating
   b) Exposed pipe report training
   c) CO_2 handling and calibration
   d) Operator Qualifications for operations of Hazardous Materials Pipeline
   e) First aid, CPR, Driving, fatigue management
   f) OSHA 10 HR training
   g) Hazwoper- Emergency response training

All specialized equipment at the storage site (drilling, geophysical survey, completions, wireline, and other) will be operated by trained, qualified and certified personnel, according to the service company providing the equipment. Subsequent data collected will be processed and analyzed by qualified and technically skilled personnel according to industry standards. Groundwater sampling and laboratory chemical analysis will be evaluated by qualified and experienced personnel who understand and regularly follow environmental sampling/chemical analysis procedures, SOPs and quality control protocols using the established sampling/chemical analysis method. HGCS will furnish relevant certifications for all vendor/subcontractor staff upon request.

A.5.b/c. Training Provider and Responsibility

HGCS or the subcontractor for the data collection activities will provide necessary training for personnel.

A.6. Documentation and Records

A.6.1 Data Management Plan

The HGSS Project Data Management plan outlined in this section has been modelled after Last et al. (2011) of the FutureGen CCUS project and provides a structural framework for how information/data generated or collected during the lifespan of the HGSS project will be stored and organized to support all phases of the project. Additionally, this section attempts to provide guidance into institutional responsibilities and requirements for managing such data, which includes the intended uses and level of quality control needed for the types of managed data and how the data will be utilized and accessible to project personnel. Due to the prolonged lifespan of the HGSS project, various data acquisition, storage devices/tools and applications of project data are subject to change as technology and CCUS industry evolves. As these changes take place the data-management strategies and tools/devices utilized, this plan will be revised and updated, as needed. Data collected and/or generated may fall into one of the following categories: formation/pre-injection testing, regulatory permitting, storage facility and pipeline design, operational monitoring, and post-injection/site closure.

The HGSS monitoring program is broken down into several focus areas:

- *Operational Monitoring*: CO_2 stream analysis, CO_2 injection rate and pressure, annular pressure/volume, corrosion monitoring, wellhead/valve leak detection/inspection
- *Hydrogeologic Testing*: Drill-stem/modular formation dynamics testing, injection fall-off testing
- *MIT Monitoring*: DTS, PNC logging
- *Direct Plume Monitoring*: downhole and surface pressure-temperature gauges
- *Indirect Plume Subsurface Monitoring*: PNC logging, DAS-3D VSP/or 3D surface seismic, Timelapse seismic, DTS
- *Above-Zone Monitoring (Ironton formation)*: DTS, downhole pressure temperature gauges and aqueous geochemistry
- *Above*-Zone *Monitoring (Shallow USDWs*): Aqueous geochemistry

Each of these monitoring focus areas produces different types of data and has distinct data-management needs (input, storage, processing, manipulation, querying, access/output). To efficiently store and utilize this array of data, several databases under individual tasks will be generated and maintained, depending on their compatibility with an overarching distributed data-management system. To the best degree possible, an attempt will be made to link these individual databases to a centralized database and file archive system, housed in an onsite operational datacenter and field office. Monitoring data will be collected under the appropriate quality assurance protocols (e.g., compliance related data will have higher QA protocols than non-compliance related data). These various data sets will be acquired and manipulated into many different file-formats and data forms (hard copy, electronic image files, physical samples etc.). Each data type will require different data-management protocols and storage/management tools which may vary from simple file management to relational databases to geographic information systems.

Technical experts will screen, validate, and/or pre-process raw data to produce “interpretation-ready” or interpreted data sets. Data with different levels of quality assurance differentiations (e.g., legacy data vs compliance-driven data) and at different levels of processing/verification will be managed separately. The following data classifications/groupings are defined:

- Level 0 – Legacy data with little or no substantial documentation or quality
- Level 1 – Raw data (acquired from some procedure or technology)
- Level 1.5 – Cleaned raw data (raw data that has been scrubbed for duplicates, gaps, corrupted data, qualification flags etc.)
- Level 2 – Processed data (cleaned or raw data that has been processed, normalized, or otherwise transformed using some model, code, algorithms, etc.). Appropriate assumptions, parameters, or algorithms of which data was processed will be referenced, labeled or annotated.

- Level 3 – Interpreted/subjective data sets (geological descriptions, stratigraphic interpretations etc.) will feature annotations, references, or labels which note all assumptions, criteria, datasets which form the basis for the interpretations.
- Level 4 – Averaged, upscaled, or statistically summarized or otherwise reconfigured parameter data sets destined for use as model/simulation input parameters. These datasets will feature references, annotations, or labels with note the capture methods, original data sets, assumptions and parameters used to generate the input and output data.

A.6.a. Report Format and Package Information

HGCS will submit semi-annual reports, annual reports, and necessary notices reports of Greenhouse Gas emissions reductions, project operations, and ongoing monitoring results pursuant to 40 CFR 146.91. HGCS will provide written notification to the UIC Program Director with the required amount of notice before select testing occurs (i.e., MIT demonstration).

All quarterly, semi-annual and annual reports from HGCS to USEPA will contain all required project data, including testing and monitoring information as specified by the UIC Class VI permit. Data will be provided in electronic or other formats as required by the UIC Program Director. Reports from HGCS to the UIC Program Director will be submitted online electronically according to specified reporting frequencies. Table A-13 summarizes the reporting frequencies for HGSS monitoring pursuant to 40 CFR 146.91.

Reports of other frequencies follows: An initial report including the results of a pressure fall-off test within 30 days following the test, an intent to demonstrate mechanical integrity at least 30 days prior to such demonstration, and an amended testing and monitoring plan once every 5 years unless it can be demonstrated that no amendment is necessary.

Table A-13. Reporting Frequencies of Monitoring-Related Data Acquired during Operational Phase

Monitoring Category	Monitoring Method		UIC Reporting Frequency
Monitoring Plan Update	Reviewed every 5 years. Updated as required		Every 5 years, reported within 1 year of amended monitoring plan 40 CFR 146.90(j)
CO_2 Injection Stream Analysis	CO_2 Stream Analysis		Semi-annual 40 CFR 146.91(a)(1)
CO_2 Injection Process Monitoring	Injection rate and volume		Semi-Annual Report 40 CFR 146.91(a)
	Injection Pressure; annulus pressure and volume		Semi-Annual Report 40 CFR 146.91(a)
Hydrogeologic Testing	Injection well pressure fall-off testing		Report sent to Program Director 30 days following test; Amended in Semi-Annual annual report once every 5 years 40 CFR 146.91(b)(1)
Injection Well Mechanical Integrity Testing	*Internal*	Continuous annulus pressure monitoring of pressurized annulus	Report sent to Program Director 30 days following test; Amended in Semi-Annual annual report once every 5 years 40 CFR 146.91(b)(1)
	External	Distributed Temperature Sensing	
Corrosion Monitoring	Corrosion coupon testing (Well and pipeline materials)		Semi-Annual 40 CFR 146.91(a)
Above-Zone Aqueous Geochemistry	Above-Zone & Shallow Groundwater Fluid sampling		Semi-Annual 40 CFR 146.91(a)
Direct Pressure Monitoring	Electronic P/T gauges		Semi-Annual 40 CFR 146.91(a)
Indirect Plume Monitoring Techniques	*Fiber/Wireline*	DTS	Semi-Annual 40 CFR 146.91(a)
		PNC Logging	*Reported in semi-annual report at a frequency of once per every five years 40 CFR 146.91(a)

Monitoring Category	Monitoring Method		UIC Reporting Frequency
	Seismic	Timelapse 3D DAS-VSP Surveys	*Reported in semi-annual report at a frequency of once per every five years 40 CFR 146.91(a)

*In the occurrence of a verified leak, this technology will be tested regardless of schedule and reported within the semi-annual report of that year.

A.6.b. Other Project Documents, Records, and Electronic Files

Other documents, records, and electronic files such as well logs, test results, or other data will be stored and maintained 10 years post site closure and provided at the request of the UIC Program Director pursuant to 40 CFR 146.91(f).

A.6.c/d. Data Storage and Duration

Records and data specified in UIC regulation will be maintained for at least 3 years and records and data specified in section § 98.3 (g) will be maintained for at least 5 years. Pursuant to 40 CFR 146.91 (f)(2/4) HGCS will store and maintain records of the CO_2 stream chemical and physical characteristics as well as monitoring data to used to develop the demonstration of the alternate post-injection site care timeframe for 10 years after site closure. All other testing and monitoring records will be kept for 10 years after its collection date (40 CFR 146.91(f)(3)).

A.6.e. QASP Distribution Responsibility

HGCS will maintain a position that will be assigned the responsibility of ensuring that all those on the distribution list will receive the most current copy of the approved Quality Assurance and Surveillance Plan.

B. Data Generation and Acquisition

B.1. Sampling Process Design

B.1.a. Design Strategy

This section describes the indirect and direct monitoring network that will be used to support collection of the various characterization and monitoring measurements needed to track development of the CO_2 plume within the injection zone and identify/quantify any potential release of CO_2 from containment that may occur. The strategy was developed based on the current conceptual understanding of the HGSS to ensure confinement of CO_2 within the reservoir and provide evidence of non-endangerment of USDWs.

Direct CO_2 Plume and Pressure Front Monitoring Strategy

Electronic downhole pressure-temperature (P/T) gauges will be used in all deep monitoring and injection wells to directly monitor the formation pressure and temperature of the injection reservoir, caprock and other key formations. Downhole P/T gauges will be deployed at a strategic depth interval within the injection reservoir to continuously measure formation pressure/temperature for injection wells. Additionally, within in-zone and above-zone monitoring wells downhole gauges will also be deployed within strategic locations within the Argenta and the Ironton formation (first permeable layer above the storage complex) to continuously monitor any changes in formation pressure and temperature. Downhole P/T gauge data will be continuously monitored by the project operator and data will be pulled, analyzed, and reported at a frequency stated in Table A-13.

Indirect CO_2 Plume and Pressure Front Monitoring Strategy

Several technologies will be deployed within the injection and deep monitoring wells to indirectly monitor the presence/absence of the CO_2 plume and the elevated pressure front. A distributed temperature sensing (DTS) fiber-optic line will be run along the outside of the long-string casing within each injection and deep monitoring (in-zone and above-zone), to continuously record temperature variations across the entire borehole. DTS data on temperature variations will be used to monitor the arrival of the CO_2 plume. DTS data will be collected continuously, relayed through the fiber optic cable to a surface unit which will transmit data to a cloud-based storage database in real-time. DTS data will be interpreted by a qualified analysist using QA/QC procedures suggested by the vendor. DTS data will be collected continuously throughout the HGSS projects life cycle (baseline, injection, and post-injection phases) and DTS analysis results will be reported at a frequency specified in Table A-13.

Three-dimensional vertical seismic profiling survey techniques will take place within the HGSS project area to track the CO_2 plume footprint and characterize the plume. A distributed acoustic sensing (DAS) fiber optic line will run along the outside of the long string casing for every injection and deep monitoring well. DAS will be primarily used for passive seismic monitoring but will periodically be utilized as a downhole acoustic receiver array within a 3D VSP seismic survey. Depending on the results of feasibility testing, surface-based 3D seismic surveys may be conducted in-place of DAS-based VSP if the technology is deemed in practical or in-effective. 3D seismic data will be processed and interpreted by qualified geoscientists who will follow accepted practices and workflows within the industry. 3D seismic data (whether surface or VSP) will be acquired one time during the baseline phase and at a minimum of once every five years during injection and post-injection phases. Results of the 3D seismic surveys (including survey design and processing parameters) will be summarized in the semi-annual report during the year in which the survey was conducted.

Pulse neutron logging (PNC) tools (either Schlumberger's Pulsar or RST tools) will be run periodically along critical formations within monitoring wells to detect and quantify CO_2 saturations within and around the storage complex. PNC data will be obtained, analyzed, and interpreted by a qualified log analysist using QA/QC practices suggested by the vendor and well-known industry standards. PNC logging will occur once during the baseline phase and once every five years during the injection and post-injection phases. PNC logging data and interpretations will be detailed in the semi-annual report for years upon which PNC data acquisition took place.

Hydrogeologic Testing Strategy

A "Pump-In/Falloff" test will be conducted in the injection zone to determine reservoir permeability and other geologic information prior to the onset of injection operations. The test will measure pumped fluid volume and rate, as well as pressure during and after pumping. The service provider selected to perform the test will be responsible for these measurements and equipment calibration. Results of hydrogeologic testing will be reported according to Table A-13.

Mechanical Integrity Data Strategy

Several technologies will be used to demonstrate mechanical integrity of the injection and monitoring wells during construction and to continuously monitor well MIT throughout the HGSS project lifecycle (baseline, injection, and post-injection phases) to prevent unintended fluid migration and protect USDWs. Upon cementing each casing string to the surface and allowing an appropriate amount time for the cement to cure, a cement bond integrity will be logged across each casing string (surface, intermediate and long). The cement bond logging tool will be an ultrasonic tool (Schlumberger's USI tool), capable of radially evaluating bond integrity and identify the presence and location of channels. Cement bond logging will be run upon setting each casing string and results of the logging will be communicated within the pre-injection testing report.

After the pre-injection testing phase is complete, external MIT will be monitored using the DTS fiber optic line ran along the entirety of each well's long string casing. DTS data will be collected continuously, relayed through the fiber optic cable to a surface unit which will transmit data to a cloud-based storage database in real-time. A qualified analyst will interpret the temperature variations measured by the DTS system for indications of a loss of internal MIT within injection and deep monitoring wells and will be reported on a semi-annual basis, throughout the lifespan of the HGSS project. DTS data and analysis will be reported at a frequency specified in Table A-13. PNC logging techniques will be utilized to verify external MIT for each injection and monitoring well by detecting the presence of CO_2 within critical formations. PNC logging will occur once during the baseline and once per every five years thereafter during the injection and post-injection phases. PNC logging results will be summarized in the semi-annual report of the years of which the logging operations was run.

Shallow Groundwater Monitoring Strategy (Quaternary sediments)

Seventeen dedicated monitoring wells will be strategically installed within shallow (<200feet) Quaternary-aged USDWs at high-risk locations across the heartland greenway storge site area. Shallow groundwater monitoring wells will be constructed, installed, and developed according to best practices outlined in ASTM-D5092[13]. The groundwater sampling method chosen for will depend on project/site specific needs in accordance with ASTM-D4448-01[14]. Shallow groundwater sampling will occur quarterly during the baseline and injection phases and will occur once every five years during the post-injection period. Analytical chemistry results of shallow groundwater fluid sampling will be reported according to the specified frequencies in Table A-13

Deep Groundwater Monitoring Strategy (Ironton formation)

Six dedicated deep groundwater monitoring wells will be strategically installed into deep (~4800feet) intervals within the first permeable layer (Ironton formation) above the confining zone (Eau Claire) at high-risk locations across the heartland greenway storge site area. Deep groundwater monitoring wells will be designed and constructed according to industry best practices. Fluid sampling will likely occur via a stainless-steel Kuster flowcell (see Attachment A) lowered on a slickline tool (or similar product). Alternative methods will be considered, and the final method of deep groundwater sampling will be chosen based on practical applicability and preservation of sample quality. Deep groundwater sampling

[13] ASTM Standard D5092-. 1992 (2016e). "Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers" ASTM International, West Conshohocken, PA, 2016. www.astm.org.
[14] ASTM Standard D4448-01. 2019. "Standard Guide for Sampling Ground-Water Monitoring Wells" ASTM International, West Conshohocken, PA, 2019. www.astm.org.

will occur quarterly during the baseline and injection phases and will occur once every five years during the post-injection period.

CO_2 Stream Monitoring Strategy

The CO_2 stream composition will be continuously monitored and analyzed using gas chromatograph to ensure stream purity. Composition will be measured both at the capture source location, and at point of injection. Results of the CO_2 stream analysis will be reported at a frequency specified in Table A-13.

Corrosion Monitoring Strategy

Corrosion coupon analyses will be monitored to aid in ensuring the mechanical integrity of the equipment in contact with the carbon dioxide. Coupons shall be sent to a company for analysis (e.g., SGS) and an analysis conducted in accordance with NACE Standard RP-0775 (or similar) to determine and document corrosion wear rates based on mass loss. Corrosion monitoring results will be reported at a frequency specified Table A-13.

B.1.b. Type and Number of Samples/Test Runs

Please refer to Table A-2 for sampling frequencies of various monitoring technologies.

B.1.c. Site/Sampling Locations

Please refer to Figure A-1.

B.1.d. Sampling Site Contingency

All testing and monitoring techniques will take place on private property of the project stakeholders and access permissions are pending ongoing landowner contracting results.

No problems of site inaccessibility are anticipated, however contingency plans are in place if need arises. In the event of inclement weather making site access difficult, sampling schedules will be reviewed, and alternative dates may be selected that would still meet permit-related conditions.

B.1.e. Activity Schedule

Please refer to Table A-2 for measurement/sampling frequencies for the various monitoring technologies.

B.1.f. Critical/Informational Data

Detailed field and laboratory documentation will be recorded in field and laboratory forms and notebooks during groundwater sampling and analytical efforts. Critical information to be documented include time and date of activity, person/s performing activity, location of activity (well/field sampling) or instrument (lab analysis), instrument calibration data, field parameter values. For laboratory analyses, many critical data are generated during the analysis process and provided to end users in digital and printed formats. Noncritical data may consist of appearance and odor of the sample, issues with well or sampling equipment, and weather conditions.

B.1.g. Sources of Variability

Several potential sources of variability related to monitoring activities exist including:

- Natural variation in formation pressure and temperature, fluid quality, and seismic activity
- Variation in fluid quality, formation pressure and temperature, and seismic activity as a result of project operations
- Changes in recharge due to precipitation (rainfall, drought, and snowfall)
- Changes in instrument calibration during sampling or analytical activity
- Different personnel collecting or analyzing samples
- Variation in environmental conditions during field sampling
- Changes in analytical data quality during life of project
- Data entry errors

Variability related to monitoring activities may be eliminated, reduced, or reconciled via the following methods:

- Gathering long-term baseline data to observe and document natural variation in monitoring parameters
- Evaluating data in a timely manner after collection to observe anomalies that can be addressed by resampling or reanalyzing
- Conducting statistical analysis of data to determine whether variability is the result of natural variation or project activities
- Maintaining weather-related data using on-site data or data collected from nearby locations (such as local airports)
- Verifying instrument calibration before, during and after sampling and analysis
- Ensuring that staff are fully trained
- Performing laboratory quality assurance checks using third party reference materials, and/or blind and/or replicate sample checks
- Utilizing a systematic review process of data that may include sample-specific data quality checks

B.2. Sampling Methods

B.2.a/b. Sampling SOPs

Shallow Groundwater

The primary groundwater sampling method will be a low-flow method consistent with ASTM D6452-99 (2005).[15] Field parameters will be measured in grab samples when a flow-through cell is not used. Prior to samples, wells will be purged to ensure groundwater samples are representative of formation water quality. Before any purging or sampling activities begin, static water levels will be measured using an

[15] ASTM, 2005, Method D6452-99 (reapproved 2005), Standard Guide for Purging Methods for Wells Used for Ground-Water Quality Investigations, ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA.

electronic water level indicator. Each monitoring well will contain a dedicated pumps (e.g., bladder pumps) to minimize potential cross contamination between wells. Given sufficient flow rates and volumes, field parameters such as groundwater pH, temperature, specific conductance, and dissolved oxygen will be recorded using portable probes and a flow-through cell consistent with standard methods (e.g., APHA, 2005).[16] Calibration of field chemistry probes will be conducted at the beginning of each sampling day according to equipment manufacturer procedures using standard reference solutions. During implementation of a flow-through cell, field parameters will be monitored continuously and will be considered stable when three successive measurements made three minutes apart meet the criteria listed in Table A-14.

Table A-14. Stabilization Criteria of Water Quality Parameters During Shallow Well Purging.

Field Parameter	Stabilization Criteria
pH, temperature, specific conductance, dissolved oxygen, turbidity	*parameter measurement until ±10% value stabilization

*Exact parameter stabilization threshold will depend upon which purge method selected from ASTM DX

Groundwater samples will be collected after field parameters have stabilized. Flow-through filter cartridges (0.45 μm) will be utilized as required and consistent with ASTM D6564-00[17]. Before sample gathering, filters will be purged with a minimum of 100 mL of well water (or more if required by the filter manufacturer). In the case of alkalinity and total CO_2 samples, exposure to the atmosphere will be minimized during filtration, collection in sample containers, and analysis. Shallow groundwater samples will be analyzed for analyte concentrations summarized in Table A-6.

For deep groundwater sampling of a slickline or wireline sampling system with a stainless steel Kuster sampling device (or equivalent), capable of collecting a fluid sample from a discrete interval. Deep monitoring wells will be purged extensively to ensure representative samples are collected and will undergo chemical analysis to determine analyte concentrations summarized in Table A-6.

B.2.c. In-situ Monitoring

Shallow groundwater

In-situ measurement of groundwater parameters is currently not planned for the projects.

[16] APHA, 2005, Standard methods for the examination of water and wastewater (21st edition), American Public Health Association, Washington, DC.
[17] ASTM, 2017, Method D6564-00, Standard Guide for Field Filtration of Ground-Water Samples, ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA.

Corrosion monitoring

The SOP for corrosion monitoring will be derived from NACE International SP0775-2013[18] or a similar protocol.

B.2.d. Continuous Monitoring

Injection process monitoring

Data related to the operational process (injection rate and volume, annular pressure, and volume) will be continuously monitored with pressure gauges, flow meters and the annulus monitoring system, all of which is linked to the surface control system controlled by HGCS. This operational data will be utilized for ensure injection operations are running safely, efficiently, and not posing a risk to overlying USDWs. Additionally, operational parameters continuously monitored may feed into reservoir models to gain insight regarding the mass and profile of the CO_2 plume.

DTS

DTS technology will continuously collect temperature data along a sensitive fiber-optic line which is ran along the outside of the long-string casing. The DTS line will collect temperature data along every 0.8 ft of the wellbore to verify internal MIT and monitor the presence or absence of the CO_2 plume.

DAS

DAS technology will receive acoustic data along a sensitive fiber-optic line which will be run along the outside of the long-string casing. The DAS line will measure the arrival times of seismic waves within the subsurface for 3D VSP seismic surveys to monitor the footprint of the CO_2 plume.

P/T gauges

Downhole pressure-temperature gauges will be deployed within completion zones of every deep monitoring and injection well to continuously measure pressure/temperature variations within the formation. Downhole pressure-temperature data will be utilized to directly monitor the presence or absence of the CO_2 plume and the elevated pressure front throughout the duration of the HGSS project.

B.2.e. Sample Homogenization, Composition, Filtration

Described in section B.2.b.

B.2.f. Sample Containers and Volumes

CO_2 Stream Analysis

[18] NACE International, 2013, SP0775, Item No.21017, Standard Practice: Preparation, Installation, Analysis, and Interpretation of Corrosion Coupons in Oilfield Operations.

The CO_2 stream will be continuously monitored vis gas chromatograph, instead of collected CO_2 samples as certain intervals.

Shallow and Deep Water Sampling

For shallow and deep groundwater sampling event, all sample bottles will be new. Sample bottles and bags for analytes will be used as received (ready for use) from the vendor or contract analytical laboratory for the analyte of interest. A summary of sample containers is presented in Table A-15. Summary of Anticipated Sample Containers, Preservation Treatments, and Holding Times for Ground Water Samples.

B.2.g. Sample Preservation

For shallow and deep groundwater samples, all sample bottles will be new. Sample bottles and bags for analytes will be used as received (ready for use) from the vendor or contract analytical laboratory for the analyte of interest. A summary of sample containers is presented in Table A-15.

B.2.h. Cleaning/Decontamination of Sampling Equipment

Each groundwater monitoring well will contain a dedicated pumps (e.g., bladder pumps) to minimize potential cross contamination between wells. Apart from maintenance, the pumps will remain in each well for the duration of the project. A non-phosphate detergent will be used to clean the outside of the pumps prior to installation. Pumps will be rinsed three or more times with deionized water. At least 1 L of deionized water will be pumped through the pump and sample tubing. Cleaned pumps and tubing will be placed in individual plastic bags for transport to the field for installation. The process for cleaning field glassware (pipets, beakers, filter holders, etc.) includes: cleaning with tap water to remove any loose dirt, washing in a dilute nitric acid solution, and rinsing at least three times with deionized water prior to use.

B.2.i. Support Facilities

When sampling of groundwater, the following equipment is needed: air compressor, vacuum pump, generator, multi-electrode water quality sonde, analytical meters (pH, specific conductance, etc.). Field analyses are usually conducted in field vehicles and portable laboratory trailers located on site.

Corrosion coupons will be detached from the CO_2 injection line in the existing CO_2 compression building.

Deployment and retrieval of well gauges will be conducted via procedures and equipment recommended by the vendor, subcontractor, or standard industry practice.

B.2.j. Corrective Action, Personnel, and Documentation

Field staff will be responsible for testing equipment properly and conducting corrective actions on broken or malfunctioning field equipment. All surface wellheads and valves will be inspected and leak inspection results maintained. In the event that corrective action cannot be completed in the field, the equipment will be returned to the manufacturer for repair or replaced. Substantial corrective actions that may impact analytical results will be documented in field notes.

B.3. Sample Handling and Custody

Geophysical logging and monitoring, and pressure/temperature monitoring are not relevant to this section, and therefore, are omitted.

Table A-15 details sample holding times which will be consistent with those described in US EPA (1974)[19], American Public Health Association (APHA, 2005)[20], Wood (1976)[21], and ASTM Method D6517-00 (2005)[22].

To preserve samples after collection, they will be placed in ice chests in the field and maintained at approximately 4°C until analysis. The samples will be kept at their preservation temperature and sent to the selected laboratory within 24 hours of collection. Analysis of the samples will be completed within the holding time specified in Table A-15. As needed, alternative sample containers and preservation techniques will be used to meet analytical requirements with approval from the UIC Program Director.

B.3.a. Maximum Hold Time/Time Before Retrieval

See Table A-15.

B.3.b. Sample Transportation

See description above.

B.3.c. Sampling Documentation

Field documentation will be compiled for all groundwater samples collected. Field notes will be archived for future reference. The groundwater sampling personnel is responsible for the sample documentation.

B.3.d. Sample Identification

Waterproof labels will be attached to all sample bottles containing information denoting project, sampling date, sampling location, sample identification number, sample type (freshwater or brine), analyte, volume, filtration used (if any), and preservative used (if any). An example of a sample bottle label is displayed in Figure A-2.

NCV OB SG 1 (fresh water)
03-02-2023
Metals, 60 ml, filtered, HNO_3

Figure A-2. Example label for groundwater sample bottles.

[19] U.S. Environmental Protection Agency (US EPA), 1974, Methods for chemical analysis of water and wastes, US EPA Cincinnati, OH, EPA-625-/6-74-003a.
[20] APHA, 2005, Standard methods for the examination of water and wastewater (21st edition), American Public Health Association, Washington, DC.
[21] Wood, W.W., 1976, Guidelines for collection and field analysis of groundwater samples for selected unstable constituents, In U.S. Geological Survey, Techniques for Water Resources Investigations, Chapter D-2, 24 p.
[22] ASTM, 2005, Method D6517-00 (reapproved 2005), Standard guide for field preservation of ground-water samples, ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA.

Table A-15. Summary of Anticipated Sample Containers, Preservation Treatments, and Holding Times for Ground Water Samples.

Target Parameters	Volume/Container Material	Preservation Technique	Sample Holding Time
Cations: Ca, Fe, K, Mg, Na, Si, Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb Se, Tl	250 ml/HDPE	Filtered, nitric acid, cool 4°C	60 days
Dissolved CO_2	2 × 60 ml/HDPE	Filtered, cool 4°C	14 days
Isotopes: ^3H, δD, $\delta^{18}O$, $\delta^{34}S$, and $\delta^{13}C$	2 × 60 ml/HDPE	Filtered, cool 4°C	4 weeks
Isotopes: $\delta^{34}S$	250 ml/HDPE	Filtered, cool 4°C	4 weeks
Isotopes: δD, $\delta^{18}O$, $\delta^{13}C$	60 ml/HDPE	Filtered, cool 4°C	4 weeks
Alkalinity, anions (Br, Cl, F, NO_3, SO_4**)**	500 ml/HDPE	Filtered, cool 4°C	45 days
Field Confirmation: Temperature, dissolved oxygen, specific conductance, pH	200 ml/glass jar	None	< 1 hour
Field Confirmation: Density	60 ml/HDPE	Filtered	< 1 hour

B.3.e. Sample Chain-of-Custody

A standardized form will be used to document groundwater sample chain-of-custody. A form is displayed in Figure A-3. A copy of the form will be provided to the person or laboratory receiving the samples as well as the person or laboratory transferring the samples. These forms will allow simplified tracking of sample status and will be archived. The groundwater sampling personnel are responsible for the chain-of-custody forms and record maintenance.

CHAIN OF CUSTODY RECORD (Page __ of __)

Heartland Greenway Carbon Storage

	MGSC ID	ISGS MVA ID	Matrix	Date Collected	Time Collected	Sampling Team	Circle analyses to be performed
1							anions, cations, TDS, alk, NH_3, NVOC
2							anions, cations, TDS, alk, NH_3, NVOC
3							anions, cations, TDS, alk, NH_3, NVOC
4							anions, cations, TDS, alk, NH_3, NVOC
5							anions, cations, TDS, alk, NH_3, NVOC
6							anions, cations, TDS, alk, NH_3, NVOC
7							anions, cations, TDS, alk, NH_3, NVOC
8							anions, cations, TDS, alk, NH_3, NVOC
9							anions, cations, TDS, alk, NH_3, NVOC
10							anions, cations, TDS, alk, NH_3, NVOC
11							anions, cations, TDS, alk, NH_3, NVOC
12							anions, cations, TDS, alk, NH_3, NVOC
12							

CHAIN OF CUSTODY		
Relinquished by:	Print Name:	Date and Time:
Received by:	Print Name:	Date and Time:
General Remarks: - Field parameters are to be recorded on separate sheets by sampling teams. - Any special laboratory instructions or remarks should be made below.		
Data Contacts:	Fund:	
Billing Contact:	Billing Address:	
Send Data To:		

Remarks:

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Figure A-3. Example chain of custody form to be used for laboratory sampling handling.

B.4. Analytical Methods

B.4.a. Analytical SOPs

Analytical SOPs are referenced in Table A-3 through Table A-8. Upon selection of a contact laboratory, other laboratory-specific SOPs will be identified. HGCS will provide the agency with all laboratory SOPs developed for specific parameters using the standard methods, upon request. The laboratory technicians performing the analyses on the samples will be trained on the SOP developed for each standard method. Technician's training certifications will be included with the biannual report.

B.4.b. Equipment/Instrumentation Needed

Table A-3 through Table A-8 detail the equipment and instrumentation in the individual analytical methods.

B.4.c. Method Performance Criteria

It is not anticipated that nonstandard method performance criteria will be needed for this project.

B.4.d. Analytical Failure

The laboratory carrying out the analyses in Table A-3 through Table A-8 will be responsible for properly addressing analytical failure according to their respective SOPs.

B.4.e. Sample Disposal

Proper sample disposal is the responsibility of each laboratory performing the analyses listed in Table A-3 through Table A-8.

B.4.f. Laboratory Turnaround

Sample analysis turnaround time varies by laboratory. A turnaround of verified analytical results within approximately two months is anticipated to meet project needs.

B.4.g. Method Validation for Nonstandard Methods

The need for nonstandard methods is not anticipated for this project. In the event that nonstandard methods are needed or proposed in the future, the USEPA will be consulted to determine additional actions that shall be undertaken.

B.5. Quality Control

B.5.a. QC Activities

Blanks

Field blanks will be utilized for both the shallow and deep groundwater sampling to identify potential contamination due to the collection and transportation process. Field blanks will be collected and analyzed for the inorganic analytes listed in Table A-6 at a frequency of 10% or more. The field and transport conditions for field blanks will be the same as those of the groundwater samples.

Duplicates

During each round of shallow groundwater sampling, a second groundwater sample is collected from one well, selected based on a rotating schedule. These duplicate samples are collected from the same source and at the same time as the original sample in a different, yet identical sample container. Duplicate samples are processed as all other samples and are used to determine sample heterogeneity and analytical precision.

B.5.b. Exceeding Control Limits

If the sample analytical results do not fall within control limits (i.e., ion balances > ±10%), further examination of the analytical results will be done as outlined in Section B.5.c below. The method indicates whether cation or anion analyses should be considered suspect based on the mass balance ratio. Suspect ion analyses are then compared to historical data and interlaboratory results, if available. The resulting analyses are then brought to the attention of the analytical laboratory for confirmation and/or reanalysis. The ion balance is then recalculated and verified. If the discrepancy is still not resolved, suspect data are noted, and may be given less importance in data interpretations.

B.5.c. Calculating Applicable QC Statistics

Charge Balance

To determine correctness of the groundwater analyses, the analytical results are evaluated based on the anion-cation charge balance calculation. All potable waters are electrically neutral; thus, the chemical analyses should produce similar negative and positive ionic activity. The anion-cation charge balance will be calculated using the formula:

$$\%\ \text{difference} = 100\,\frac{\Sigma\text{cations} - \Sigma\text{anions}}{\Sigma\text{cations} + \Sigma\text{anions}}$$

where the sums of the ions are given in milliequivalents (meq) per liter, and the acceptable charge balance is ±10%.

Mass Balance

If the charge balance acceptance criteria are not acceptable, the ratio of the measured TDS to the calculated TDS will be calculated using the formula:

$$1.0 < \frac{measured\ TDS}{calculated\ TDS} < 1.2$$

with anticipated values between 1.0 and 1.2.

Outliers

A determination of potential statistical outliers is essential before the statistical evaluation of groundwater. The project will refer the US EPA's Unified Guidance (March 2009)[23] for the selection of recommended statistical methods to identify outliers in groundwater chemistry data sets as appropriate. These methods in the document include Probability Plots, Box Plots, Dixon's test, and Rosner's test. The EPA-1989 outlier test[24] may also be used as an additional screening tool to identify potential outliers.

B.6. Instrument/Equipment Testing, Inspection, and Maintenance

1. DCS system will be maintained by operator according to manufacturer standards
2. DTS/DAS will be maintained by vendor according to manufacturer standards
3. P/T gauges will be maintained by vendor according to manufacturer standards
4. Logging tool equipment will be maintained as per wireline industry best practices (Attachment C).
5. For groundwater sampling, field equipment will be maintained, factory serviced, and factory calibrated per manufacturer's recommendations. Spare parts that may be needed during sampling will be included in supplies on-hand during field sampling.
6. For all laboratory equipment, testing, inspection, and maintenance will be the responsibility of the analytical laboratory per standard practice, method-specific protocol, or NELAP requirement.

B.7. Instrument/Equipment Calibration and Frequency

B.7.a. Calibration and Frequency of Calibration

CO_2 process equipment along the pipeline and at sources will be calibrated using industry standards. The Daniel Sr orifice meter calibration will be conducted monthly and is based on lease gross volume (Mcf/day). If a monitoring device along the pipeline does not meet calibration requirements HGCS or the operator will take the following steps:

1. Shut down facility, contact customer to witness steps 2-6
2. Close data for the month
3. Isolate connection facility, and change out failed equipment
4. Create new opening ticket
5. Calibrate newly installed equipment
6. Have customer sign off witness form and return to normal.

[23] U.S. Environmental Protection Agency (US EPA) 2009, Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, US EPA Cincinnati, OH, EPA-530/R-09-007.
[24] U.S. Environmental Protection Agency (US EPA) 2009, Data Quality Assessment: Statistical Methods for Practitioners, US EPA Cincinnati, OH, EPA-QA/G-9S.

All field and downhole gauges will be calibrated prior to use by the equipment supplier. Gauges will be recalibrated as needed based on results of inspection, or after any repairs or maintenance. Logging tool calibration will be conducted as per the standards of the service company providing the equipment. Calibration frequency will be determined by standard industry practices. The CO_2 stream gas chromatographs and mass flow meters will be calibrated prior to installation according to manufacturer specifications.

Portable field meters or multiprobe sondes used to determine field parameters of groundwater samples (e.g., pH, temperature, specific conductance, dissolved oxygen) are calibrated according to manufacturer recommendations and equipment manuals (Hach, 2006)[25] before each sample collection. Recalibration is performed if any components fail to meet calibration standards, or do not stabilize during sampling.

Instrument/equipment calibration is not required DTS/DAS lines.

B.7.b. Calibration Methodology

Calibration of the orifice meters will be carried out using the carrier gas to validate the characteristics of the approved CO_2 composition using methods seen in Table A-3.

Logging tool calibration methodology will follow standard industry practices in Attachment C. Calibration of all field and downhole gauges, gas chromatographs, and mass flow meters will be conducted by the respective manufacturers/suppliers as per their normal procedures.

Groundwater sampling calibration standards typically require 7 and 10 for pH, a potassium chloride solution with a value of 1413 microseimens per centimeter (µS/cm) at 25°C for specific conductance, and a dissolved oxygen calibration to a 100% dissolved O_2 solution. Calibration for the pH meters is performed according to the manufacturer's specifications, using a 2-point calibration bounding the range of the sample. For coulometry, sodium carbonate standards with a concentration of 4,000 mg CO_2/L are routinely analyzed to calibrate instrument.

B.7.c. Calibration Resolution and Documentation

Logging tool recalibration and documentation will be conducted as needed by the logging company, following standard industry practices in Attachment B.

Groundwater sampling equipment calibration occurs regularly, and values are recorded in sampling records, with any errors in calibration noted. For parameters where calibration resolution is not feasible, redundant equipment may be used so loss of data is minimized.

[25] Hach Company, February 2006, Hydrolab DS5X, DS5, and MS5 Water Quality Multiprobes User Manual, Hach Company, 73 p.

B.8. Inspection/Acceptance for Supplies and Consumables

B.8.a/b. Supplies, Consumables, and Responsibilities

Individual vendors selected and approved by HGCS are responsible for ensuring that all supplies and consumables for field and laboratory operations are inspected, and acceptable for data collection activities. Procurement of supplies and consumables related to groundwater analyses will be the responsibility of the laboratory conducting water analyses, in accordance with established standard methodology and operating procedures.

B.9. Nondirect Measurements

B.9.a. Data Sources

Plume development will also be monitored via DTS, 3D VSP/or 3D surface seismic and pulsed neutron logging techniques. Pulsed neutron logging detects CO_2 concentration in a well and repeat logging runs will be compared to the baseline run conducted before injection operations being. DTS monitors variations in temperature along the wellbore at a high resolution, measured a specified acquisition rate (TBD during feasibility study). Distributed acoustic sensing measures strain caused by acoustic waves passing through/near the fiber optic cable ran along the long-string casing and can act as downhole VSP geophones. This technology can be used to generate 3D VSP surveys to track the CO_2 plume.

Repeatability of subsequent seismic surveys is crucial for accurate comparison. Therefore, to ensure survey quality, the locations for shots and procedure of acquisition of sequential surveys must be consistent. Seismic surveys will be compared to a baseline survey collected prior to injection operations to track and monitor plume growth and movement.

B.9.b. Relevance to Project

Time-lapse seismic surveys and scheduled PNC logging will be used to track movement and growth of the CO_2 plume in the subsurface. After initial baseline testing is conducted prior to injection, processing and comparing subsequent surveys will allow project managers to monitor the extent of the plume, ensuring that the plume does exceed the boundaries of the intended storage reservoir. Numerical modeling will be conducted throughout the project to predict the CO_2 plume growth and migration over time by combining the processed seismic data with the existing geologic model.

B.9.c. Acceptance Criteria

The collecting of seismic data following standard industry practices will ensure accuracy in the resulting modeling and monitoring. Similar ground conditions, seismic shot points located within acceptable limits, carefully inspected and operational geophones, and uniform seismic input signal will be used for each survey to ensure repeatability.

Seismic data processing QA checks will be conducted done according to industry standards, including reformatting to Omega structured files, geometry application, amplitude compensation, predictive deconvolution, elevation statics correction, RMS amplitude gain, velocity analysis every 2 km, NMO application using selected velocities, CMP stacking, random noise attenuation, and instantaneous gain.

B.9.d. Resources/Facilities Needed

HGCS will subcontract all necessary resources and facilities for seismic monitoring, in-zone pressure monitoring, groundwater sampling, and other required monitoring equipment and services.

B.9.e. Validity Limits and Operating Conditions

Intraorganizational verification by trained and experienced personnel will ensure that all seismic surveys and numerical modeling are conducted according to standard industry practices.

B.10. Data Management

B.10.a. Data Management Scheme

HGCS or a designated contractor will maintain all project data as provided elsewhere in this permit. Data will be backed up on secure servers. Data will be maintained for the time specified in section A.6(c/d) of this document.

B.10.b. Recordkeeping and Tracking Practices

All records of collected data will be securely kept and properly labeled for auditing purposes. Various end devices will be collected and stored in a Programmable Logic Controller (PLC) locally and then on a separate system for archiving and reporting.

B.10.c. Data Handling Equipment/Procedures

All data storage equipment will be properly maintained and operated according to standard industry techniques. Figure A-4 shows the overall data handling architecture for the HGSS. The center point of the field devices will be the PLC. PLCs will sit on a hardened network, secured from the office/data network, and talk to end devices (flow computers, sensors, pump motors, valves, compressors, chromatographs, monitoring site equipment, etc.). A Wide Area Network (WAN) will connect to each location's local network including the secured network. The WAN is comprised of leased circuits, cellular networks and satellites all connected to the Internet (some sites may have multiple connection types for redundancy). Each site on the WAN will communicate through a secure VPN tunnel to a central location or hub at the corporate office. A Communication Manager Software will communicate with the field devices (primarily the PLCs) to poll data for both real time, control room monitoring and historical or measurement data. This tool may also talk directly to the Flow Computers and Chromatographs for historical (measurement) data collection. HGCS will implement SCADA (Supervisory Control and Data Acquisition) Software that will communicate with the Communication Manager software to collect data required to monitor and control the system. This communication will be bidirectional with data being polled for monitoring and poked or pushed to the PLC to update valve positions, start / stop pumps, compressors, etc. Ticketing or Measurement software will also talk to the Communication Manager Software to retrieve historical data for measurement purposes. Reporting software will also talk to the Communication Manager Software for both historical data and in some instances real time data for reporting purposes.

Meter data is captured via a gas calculating program such as FlowCal, this software calculates the data from the measurement equipment, allowing for reports such as System balancing, Monthly Close, SOX audit requirements, customer reporting, and quality management. This software uses standard calculations from API, AGA, and GPA, and uses the SCADA systems to integrate from upstream to downstream customer. Metered data will be gathered at each flow computer site (FB2200/ROC800 or OMNI6000) and brought back to SCADA.

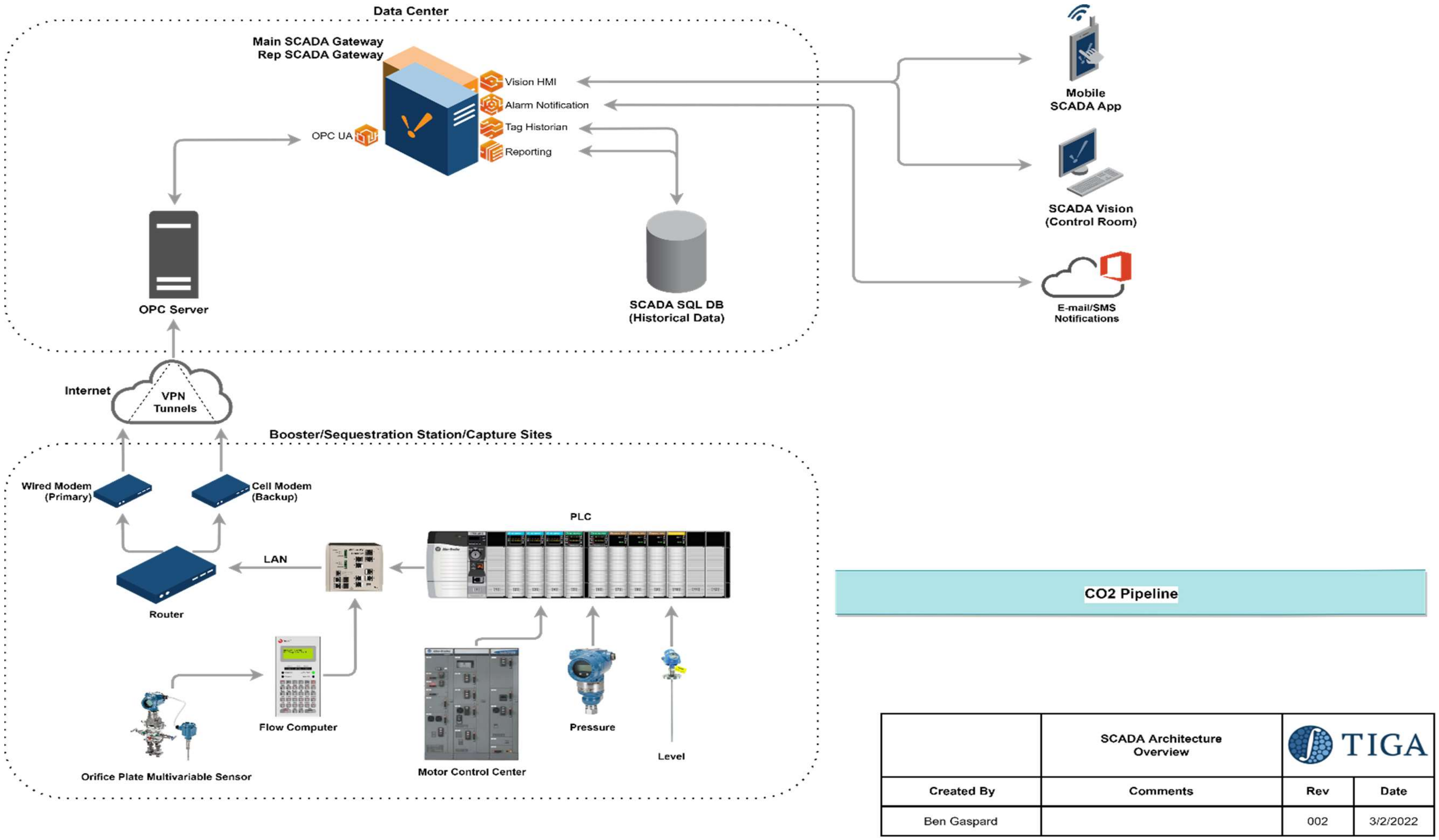

Figure A-4. Overall data handling architecture for the HGSS.

HGCS will follow the international standard for developing an automated interface between control systems and enterprises, ISA-95 Hierarchy Flow[26]. This standard contains five levels in an automation pyramid (Figure A-5) of data that are outlined below to expand upon the ISA-95 Hierarchy Flow.

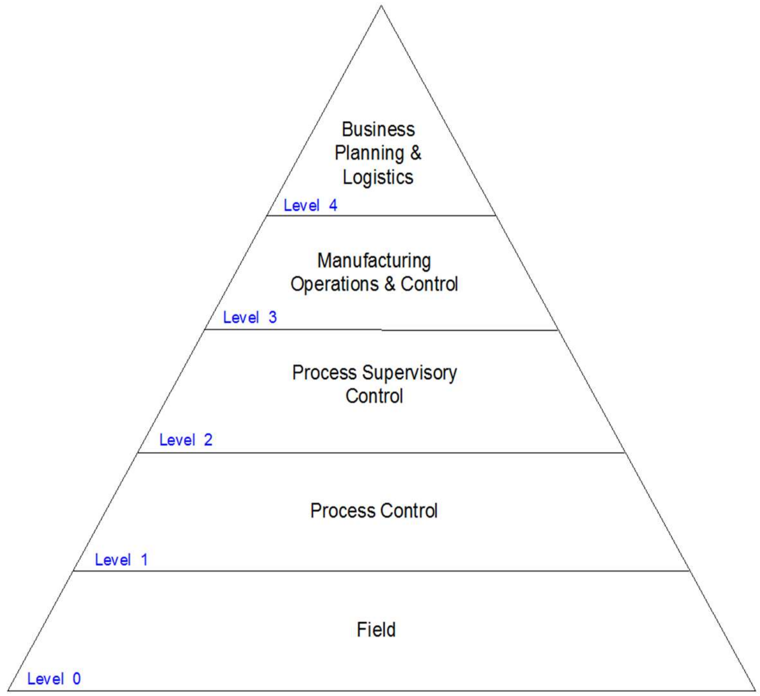

Figure A-5. The HGCS ISA-95 hierarchy flow model automation pyramid.

Level 0 (Sensors)

- Defines the actual physical processes.
- Defines the activities involved in sensing and manipulating the physical process.
- Level) elements are the sensors and actuators attached to the control function.

Level 1 (PLCs & RTUs)

- Defines the activities of monitoring and controlling the physical process.
- Level 1 automation and control systems have real-time responses measured in sub seconds and are typically implemented in PLCs and DCS.

[26] International Society of Automation (ISA) 95.00.01-2010, Enterprise control System Integration, Research Triangle Park, NC.

Level 2 (SCADA & HMI)

- Defines the system of software and hardware elements that allows industrial organizations to:
    - Control industrial processes locally or at remote locations.
    - Monitor, gather, and process real-time data.
    - Directly interact with devices such as sensors, vales, pumps, motors, and more through HMI software.
    - Records events.

Level 3 (MES)

- Defines the activities that coordinates production resources to produce the desired product.
- Level 3 functions directly related to production are usually automated MES.

Level 4 (ERP)

- Defines business-related activities that manage a manufacturing organization.
    - Manufacturing-related activities includes establishing the basic plant schedule (such as material use, delivery, etc.), determining inventory levels, logistics control, etc.
    - ERP logistic systems are used to automate level 4 functions.

Below is a NCV capture site data flow example:

1. A Sensor processes the physical variable to be measured (ex. Pipeline pressure), this data is converted to a 4-20ma analog signal and sent to the PLC. For a flow sensor the data is converted to 4-20ma or communicated serially to a Flow Computer (FC).
2. The PLC receives the analog signal and scales it to engineering units (ex. 0-2000 psi), this data is stored on the PLC memory and can be used for control and alarming functions. The Flow Computer receiving flow data will perform the flow calculations based on the variables and the EFM data is stored in the flow computer.
3. The PLC and Flow Computer are networked to the Wide Area Network (WAN) where the data will flow to SCADA. This WAN connection will be redundant (VSAT and Cellular Modem) or Dual Cellular Modem depending on site location.
4. The SCADA system will poll the data from all the PLCs and Flow Computers on the Pipeline system and store it on the OPC Server.
    a. The SCADA System will have multiple modules (refer to Overall Architecture) including:
        i. SCADA Gateway with modules:
            1. Tag Historian
            2. Vision
            3. OPC UA Client
            4. Reporting
            5. Alarm Notification
            6. SMTP
        ii. SQL Server for Historical Data
    b. The SCADA system is visualized in the control room or SCADA Mobile Apps.

B.10.d. Responsibility

The primary HGCS project manager will be responsible for ensuring proper data management is maintained.

B.10.e. Data Archival and Retrieval

All data will be compiled and stored by HGCS. These data will be maintained for auditing purposes as described in section B.10.a.

B.10.f. Hardware and Software Configurations

All HGCS and third-party hardware and software configurations will interface appropriately.

B.10.g. Checklists and Forms

Checklists and forms will be generated and completed as necessary.

C. Assessment and Oversight

C.1. Assessments and Response Actions

C.1.a. Activities to be Conducted

Please refer to Table A-1 and Table A-2 for a summary of work to be performed and proposed work schedule. The frequency of groundwater quality data collection is also outlined in Table A-2. After completion of groundwater sample analysis, the results will be reviewed for QC criteria as noted in section B.5 above. If the data fails to meet the quality criteria set in section B.5, samples will be reanalyzed while still within the sample holding time. If sample holding time has expired, additional samples may be collected, or sample results may be excluded from data evaluations and interpretations. An evaluation of data consistency will be performed according to procedures described in the U.S. EPA 2009 Unified Guidance (U.S. EPA, 2009)[27].

C.1.b. Responsibility for Conducting Assessments

Each organization gathering data will be responsible for conducting their own internal assessments. All stop work orders will be handled internally within each individual organization.

C.1.c. Assessment Reporting

All assessment information will be reported to the HGCS project manager specified in A.1.a/b.

[27] U.S. Environmental Protection Agency (US EPA) 2009, Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, US EPA Cincinnati, OH, EPA-530/R-09-007.

C.1.d. Data Corrections

All corrections which may affect a single individual organization's data collection responsibility shall be addressed, verified, and documented by the individual project managers, and communicated to the other project managers as necessary. Corrective actions affecting multiple organizations shall be addressed by all project managers and communicated to other members on the distribution list for this document. Integration of information from multiple monitoring sources (operational, in-zone monitoring, above-zone monitoring) may be required to determine whether data and/or measurement method corrections are required, as well as the most cost-efficient and effective action to implement. HGCS will coordinate multiorganization assessments and correction efforts as needed.

C.2. Reports to Management

C.2.a/b. QA Status Reports

QA status reports are not required unless there are significant adjustments to the methods and procedures listed above. If any testing or monitoring techniques are changed, this document will be reviewed, and appropriately updated after consultation with the UIC Program Director. Revised QASPs will be distributed by HGCS to the full distribution list noted at the beginning of this document.

D. Data Validation and Usability

D.1. Data Review, Verification, and Validation

D.1.a. Criteria for Accepting, Rejecting, or Qualifying Data

Validation of data will include a review of concentration units, sample holding times, and a review of duplicate, blank and other QA/QC results. HGCS will hold copies of all laboratory analytical test results and/or reports. Analytical results will be reported regularly, based on the approved permit frequency conditions. In these periodic reports, data will be presented in either graphical and tabular formats as appropriate to represent general groundwater quality and identify variability in each groundwater monitoring well with time. All groundwater quality results will be documented a database or spreadsheet with regular data review and analysis. After sufficient data have been collected, additional methods, such as those described in the U.S. EPA 2009 Unified Guidance (U.S. EPA, 2009)[28], will be used to evaluate intrawell variations, to determine if significant changes have occurred which could result from CO_2 or brine seepage beyond the anticipated storage reservoir.

[28] U.S. Environmental Protection Agency (US EPA) 2009, Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, US EPA Cincinnati, OH, EPA-530/R-09-007.

D.2. Verification and Validation Methods

D.2.a. Data Verification and Validation Processes

Verification will include a review of the following:

- Documentation and maps to verify the boundaries of the project, including the location of monitoring and measurement equipment, and procedures for data quality assurance and quality control; and
- The operator's CCS project's risk rating for determining its contribution to the Buffer Account as calculated under Appendix G.
- All plans, assessments, and reports for conformance with the UIC Regulation and the requirements of the UIC regulation.

See sections D.1.a. and B.5.

Appropriate statistical software will be utilized to determine data consistency.

D.2.b. Data Verification and Validation Responsibility

HGCS will designated subcontractor will verify and validate sampling and monitoring data.

D.2.c. Issue Resolution Process and Responsibility

HGCS will designate a Site Coordinator, who will oversee the groundwater data handling, management, and assessment process. All staff involved with these procedures will consult with the Site Coordinator to determine required actions to resolve issues.

D.2.d. Checklist, Forms, and Calculations

Checklists and forms shall be specifically developed to meet permit requirements. These checklists will largely depend on the parameters that are being tested as well as standard operating procedures of the subcontractors and labs that will be gathering samples and conducting the analyses. HGCS will provide these forms and checklists to the UIC Program Director upon request.

D.3. Reconciliation with User Requirements

D.3.a. Evaluation of Data Uncertainty

Statistical software will be used to ensure data consistency using methods consistent with U.S. EPA 2009 Unified Guidance (USEPA, 2009)[29].

[29] U.S. Environmental Protection Agency (US EPA) 2009, Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, US EPA Cincinnati, OH, EPA-530/R-09-007.

D.3.b. Data Limitations Reporting

Each organization's project manager will be responsible for ensuring that data presented by their respective organizations is developed with the appropriate data-use limitations.

HGCS will use the current operating procedure for the use, sharing, and presentation of data for the HGSS project. This procedure has been developed to ensure quality and internal consistency, and to facilitate tracking and record keeping of data, end users, and all associated publications.